Simultaneous Laser Wavelength Locking and Spectral Filtering using Fiber Bragg Grating

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Abstract. We demonstrate an optical scheme allowing for simultaneous wavelength locking and spectral filtering using a single fiber Bragg grating. We observe substantial increase of extinction ratio and reduction of the wavelength chirp. The scheme also provides stable wavelength necessary for dense WDM system applications.

Direct modulation is the simplest modulation technique for semiconductor lasers. However it is prone to strong wavelength chirp, and high extinction ratio is difficult to achieve due to relaxation oscillations (pulse ringing occurs when OFF state current is close to threshold current). One of the solutions is spectral filtering. When the output of the laser is passed through a narrow optical filter, the chirp can be reduced and extinction ratio increased[1,2].

However this scheme relies on precise relative spectral positions of the spectral filter and laser wavelength. Without a wavelength locking mechanism stable operation is not possible. Moreover, the bulk optical filters[1,2] have poor wavelength selectivity and high insertion loss.

Recently a wavelength locking scheme based on fiber Bragg grating was demonstrated[3]. We propose a new method, which allows to combine the wavelength locking with spectral filtering using a single fiber Bragg grating.

The optical scheme is shown in Fig.1. The standard Lucent Technologies isolated DFB laser module (ILM) has a thermoelectric cooler and thermistor inside the package assembly, which allow for control and monitoring of the laser chip temperature. The ILM output is connected to the port 1 of 3-port Optical Circulator (OC). Port 2 of the OC is connected to the 95:5 fiber coupler with low polarization dependent loss. The output of the same branch of the fiber coupler is followed by FG and an optical attenuator. The output of the optical attenuator is connected to photodetector PD1 and provides one of the signals for the differential wavelength stabilization scheme similar to one used in [3]. 95% of the light reflected from the FG goes back into the port 2 of the OC, and 5% of it is coupled into the second photodetector (PD2), which gives the second signal for the wavelength stabilization scheme. The optical signal reflected by FG into port 2 of OC provides the useful output at the port 3.

The laser was biased at 70mA DC current and driven by 2.5Gb/s bit pattern with 2V peak-to-peak amplitude, corresponding to $I_{peak\text{-}to\text{-}peak}$=40mA. As shown in Fig.3, the laser output wavelength is stable under 2.5Gb/s direct modulation.

The modulation of directly modulated semiconductor laser is accompanied by frequency modulation. The time-averaged optical spectrum has two maxima corresponding to ON and OFF states, which is shown in Fig.4 (dashed line). Due to the limited spectrometer resolution (1Å) this splitting of the maximum is washed out. The ON state has higher optical power and therefore it has higher peak in the spectrum.

When the laser operates in the scheme shown in the Fig.1, its wavelength is locked to the red slope of the reflection spectra of the fiber grating. Since the optical power in ON state is higher than in OFF state, locking occurs at the wavelength close to the ON state peak. Therefore the short wavelength part of the laser spectrum is transmitted into the output, while the longer wavelength is not (solid line in the Fig.4) and the signal in OFF state is filtered out. This results in two effects: reduction of the wavelength chirp and increase of the extinction ratio.

The eye diagram of the standalone ILM under these drive conditions is shown in Fig.5a. The laser threshold current is 9.3mA, the current in ON and OFF states is 90mA and 50mA respectively, so the extinction ratio is about 3dB. We also measured the wavelength chirp, which was about 0.9 Å.

Fig.5b shows the eye diagram under the same electrical modulation conditions as in Fig.5a, but with spectral filtering. The extinction ration has improved substantially (up to 16.3dB). Some noise in the ON level corresponds to the ON-state chirp transformed into amplitude variation by the fiber grating. Very low optical power in the OFF-state makes it difficult to estimate the wavelength in the OFF-state accurately. The averaged ON-OFF chirp is about 0.3-0.5Å, i.e. 2 to 3 times lower than for the ILM without spectral filtering.

The increased extinction ratio and reduced chirp should allow for higher distance of transmission.

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2. P.A. Morton, G.E. Shtengel, L.D. Tzeng, et al, *Electron.Lett*., v.33(4), p.310, Feb. 1997.
3. S.T. Lee, Y. Park, C.J. Chae, OFC'98, paper WM45, p.381, Feb. 1998.

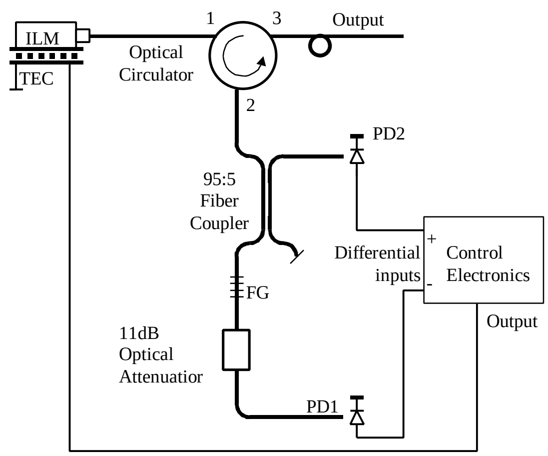

Fig.1 The schematic of the experimental setup.

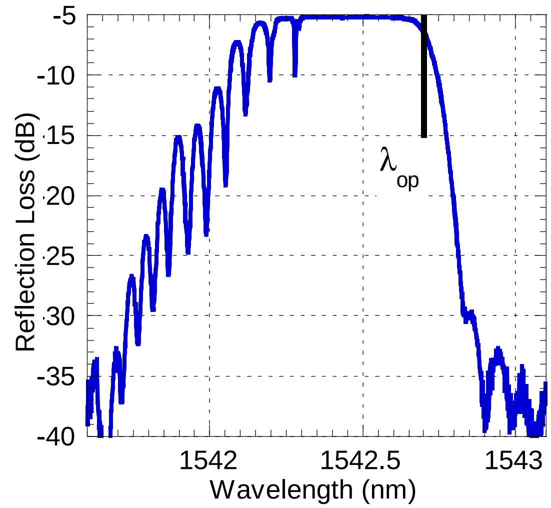

Fig.2 Reflection spectrum of the fiber grating

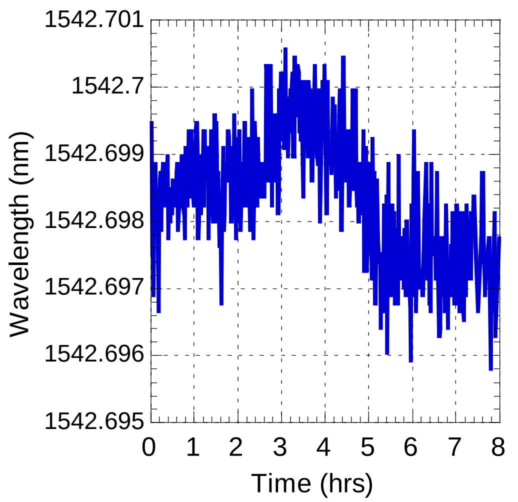

Fig.3 The wavelength of the ILM under 2.5Gb/s modulation as a function of time.

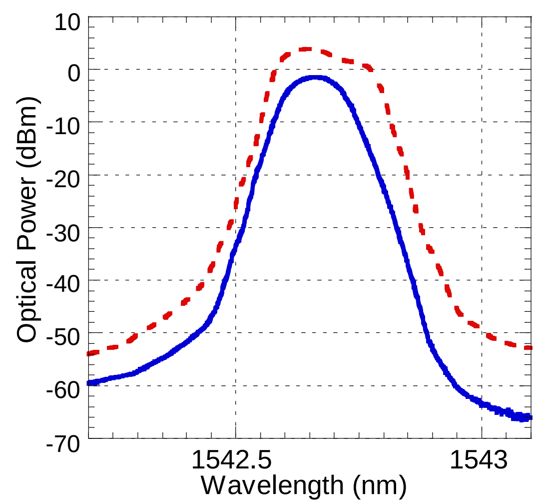

Fig.4 Laser spectrum under 2.5Gb/s modulation before (dashed) and after spectral filtering (solid).

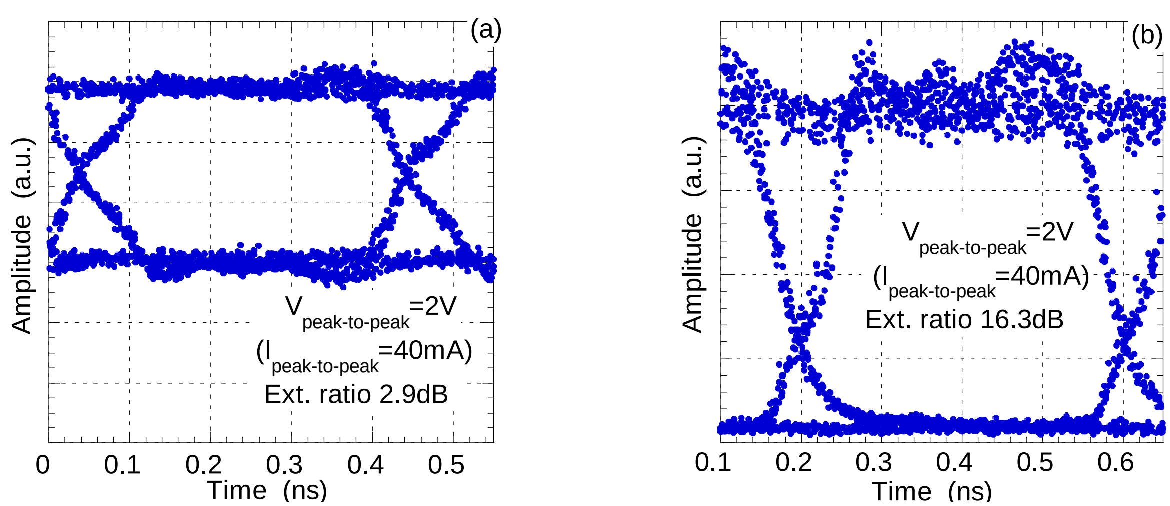

Fig.5 Eye diagram under 2.5Gb/s modulation. Standalone ILM (a), and the output of the optical scheme in Fig.1 (b).